REPLACED BY ART 34 AMDT

REC'D 05 JUL 2004 WIPO PCT

10/521009

Rec'd PCT/PTO 12 JAN 2005

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PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 32087PC01	**FOR FURTHER ACTION** See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/DK 03/00457	International filing date *(day/month/year)* 01.07.2003	Priority date *(day/month/year)* 12.07.2002
International Patent Classification (IPC) or both national classification and IPC G01B11/30		
Applicant LUKA OPTOSCOPE APS et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 7 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 9 sheets.

3. This report contains indications relating to the following items:

   I ☒ Basis of the opinion
   II ☐ Priority
   III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   IV ☐ Lack of unity of invention
   V ☒ Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   VI ☐ Certain documents cited
   VII ☐ Certain defects in the international application
   VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
03.02.2004	01.07.2004
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized Officer Dighaye, J-L Telephone No. +49 89 2399-2823

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/DK 03/00457

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:

Description, Pages

1-25 as originally filed

Claims, Numbers

1-50 received on 18.06.2004 with letter of 16.06.2004

Drawings, Sheets

1/18-18/18 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   - ☐ the description, pages:
   - ☐ the claims, Nos.:
   - ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)).

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-50
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-50
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-50
	No:	Claims	

2. Citations and explanations

see separate sheet

1. The present application is directed to five "aspects" or objects:
   - first: apparatus for measuring geometrical profiles of periodic microstructures of a sample (see p. 6, l. 1 seq), comprising the embodiments of claim 1 and claim 26;
   - second: non-destructive method for measuring such profiles (see p. 7, l. 27 seq.), comprising the embodiments of claim 14 and claim 29;
   - third: use of such method (claims 15-23 and 40-48, respectively);
   - fourth: computer program code for determining such profiles (see p. 9, l. 8 seq.), comprising the embodiments of claim 24 and claim 49;
   - fifth: computer readable medium carrying such code (see p. 9, l. 33 seq.), comprising the embodiments of claim 25 and claim 50.

   The broadest object appears to be the fourth one, since all the other objects comprise or make use of its features, while comprising additional features. Hence claim 24 and alternative claim 49 will be discussed first.

2. With regard to claims 24 and 49, a prior art document comprising several similarities is D1 = WO-A-02/14840, referring itself to the background art (p. 1, l. 19 seq.).

   Indeed, D1 discloses that there are known methods of measuring microstructures on a sample "by measuring characteristics of radiation reflected or diffracted by the sample (e.g., reflection intensity, polarization state, or angular distribution)" (p. 1, ll. 28-30).
   This corresponds to the step of "resolving" of claim 24 and claim 49. (Regarding illumination wavelengths, see p. 2, l. 16).

   Further, according to D1, p. 2, l. 7 seq., several methods are known wherein the measured data are compared with the results predicted by a theoretical model whose parameters can be adjusted (p. 2, l. 12). "First, a set of trial values of the measurement parameters is selected" (p. 2, ll. 17-18).
   This has similarities with the step of "comparing" of claim 24 and claim 49. In order to perform the comparison, a known geometrical profile is selected either from a database (claim 24) or by variation of parameters (claim 49), which is equivalent or similar to the disclosure of D1.

However, in claims 24 and 49, the selection is "performed using minimum norm techniques". Since, at that stage, D1 does not disclose the use of such techniques, claims 24 and 49 (and a fortiori the other independents claims, which are narrower in scope) are manifestly novel over D1.

Yet, as a last step, D1 discloses an iterative "automated fitting optimization algorithm" (p. 2, ll. 23-26) in which the parameter values are repeatedly adjusted until the discrepancy between the measured and predicted signal characteristic is minimised. Typically, "the mean-square error of the signal characteristic components" (p. 2, l. 26) is minimised.
This is equivalent to the step of "repeating adjusting" of claim 24 and claim 49, and to the minimum norm techniques recited in the previous step of such claims.

In other words, D1 discloses a method having three steps comparable with those of the present "fourth aspect", except that D1 explicitly mentions mean-square error techniques in the third step only, whereas, in the present claims, minimum norm techniques are recited in the second step only. It appears, however, that "a minimisation least square fitting procedure is applied" (p. 22, ll. 5-6) in the third step as well.

D1, however, does not disclose or even hint at all the features of present claim 24 and claim 49. In particular:

- D1 discloses a general interpolation method which may be used for a variety of instruments associated with different optical measurement types (see p. 11, ll. 8-9);

- The present concept of collecting and comparing light from both the zeroth and higher diffraction orders departs from the teaching of D1. On the one hand, the inventors of D1 are fully aware of the requirements for scatterometry, i.e. assessing reflectivity versus incidence angle, p. 11, l. 11, as explained in detail in several passages such as p. 15, l. 24 - p. 16, l. 8, in which theoretical models are presented. They also refer to the prior art of measuring angular distribution characteristics at different collection angles (p. 1, 28-30 and p. 2, ll. 15-16). Accordingly, they propose that "the measurement instrument may be configured to selectively exclude, or accept, a particular diffracted order or orders" (p. 12, ll. 3-

4). However, on the other hand, "in typical applications, only the zeroth order is used" (p. 12, ll. 4-5). Thus it appears that the inventors of D1 rely on results of theoretical models which can be compared with measurements using only the zeroth order, so that there is no motivation, for the skilled person, to adapt collection or comparison means to take both zeroth and higher diffraction orders into account.

3. D2 = US-A-5 963 329 is a further prior art document having several similarities with the subject-matter of claims 24 and 49.

For instance, D2 discloses a method and apparatus for determining geometrical aspects of a sample. Such aspects are derived from an optical signal by comparing the optical signal with a calculated signal, and adjusting the model structure until an agreement is found between the calculated and the measured signals.

In D2, though, like in the preferred embodiment of D1, only the zeroth diffraction order is taken into account since only a small solid angle portion of the diffraction pattern is measured, see col. 5, ll. 1-5 and the embodiment of Fig. 9 and col. 8, ll. 63-65. No measurements of other diffraction orders are assumed to be needed since they are compared with the results of "a computer program that predicts the percentage of reflected energy diffracted into the zeroth order" (col. 5, ll. 40-41).

Thus there is no hint, in D2, towards arriving at the unambiguous determination of geometrical aspects of semi-periodic structures by taking several diffraction orders into account, as it is presently the case.

Finally, the skilled person starting from D2 as the closest prior art would not consult D1 since he would read that "the computational representation of the associated structure geometry (e.g., profile shape) is not required for subsequent measurement processes" (D1, p. 17, ll. 18-19). Hence D1 and D2 fail to provide a combination of features obviously leading to claim 24 or claim 49.

4. The other documents cited in the International Search Report are considered even less relevant than D1 and D2.

As told in point 1 above, the other claimed aspects are more restrictive and specific than the fourth aspect examined hitherto.

Therefore, all the claims on file appear to be novel and inventive in view of all the cited documents.

5. Remark: If the application is prosecuted, for instance in the European phase, the prior art of D1 and D2 should be briefly acknowledged in the description; the relevant passages of the description should be adapted to the present claims; and the claims should comprise reference numerals whenever necessary.

CLAIMS

1. An apparatus for measuring geometrical profiles of periodic microstructures of a sample, the apparatus comprising

- a light source for emission of a light beam,

- polarizing means for polarizing the emitted light beam,

- focusing means for focusing the polarized light beam on the microstructures of the sample so as to provide, at a number of microstructures, a plurality of illumination angles simultaneously,

- a collection means for collecting light diffracted from the illuminated microstructures,

- resolving means for resolving the collected light into diffraction data relating to illumination angles, polarization angles, diffraction orders, and illumination wavelengths, and

- a reconstruction algorithm for determining the geometrical profile of the illuminated microstructures, the reconstruction algorithm being adapted to perform the following steps:

    - comparing the resolved diffraction data with modeled diffraction data from a known geometrical profile, the known geometrical profile being selected from a database of pre-defined families of profiles, the selection being performed using minimum norm techniques,

    - repeating adjusting the geometrical profile of the known selected geometrical profile until the modeled diffraction data matches the resolved diffraction data within predetermined tolerances.

2. An apparatus according to claim 1, wherein the light source comprises a broadband light source, such as Xenon, Deuterium, or halogen lamp.

3. An apparatus according to claims 1 or 2, wherein the focusing means comprises a lens system.

4. An apparatus according to claim 1, wherein the light source comprises a substantially monochromatic light source, such as a laser.

5. An apparatus according to any of claims 1-4, wherein the collection means comprises a lens system.

6. An apparatus according to any of claims 1-5, wherein the focusing means and the collection means each comprises a lens system.

7. An apparatus according to claim 6, wherein the lens systems of the focusing means and the collection means are the same lens system.

8. An apparatus according to any of claims 1-7, wherein the polarizing means comprises a beam splitter, the beam splitter generating a reference beam and an illumination beam.

9. An apparatus according to any of claims 1-8, wherein the resolving means comprises an imaging detection system.

10. An apparatus according to claim 9, wherein the imaging detection system comprises means for generating a plurality of light beams having different center wavelengths and propagating in different directions.

11. An apparatus according to claim 10, wherein the imaging detection system further comprises an array of light sensitive elements, the array of light sensitive elements being adapted to be illuminated by the generated plurality of light beams.

12. An apparatus according to claim 9, wherein the imaging detection system comprises an array of color light sensitive elements, the color sensitivity being provided by a color mask positioned in front of the light sensitive elements.

13. An apparatus according to any of claims 11 or 12, wherein the array of light sensitive elements forms part of a CCD array, an InGaAs array, a PbSe array, a PbS array, a Superconduction Tunnel Junction array, or any combination thereof.

14. A non-destructive method for measuring geometrical profiles of periodic microstructures of a sample, the method comprising the steps of:

- providing a light source for emission of a light beam,

- polarizing the emitted light beam, and transmitting the polarized light beam to a refractive member,

- focusing the transmitted and polarized light beam on the microstructures of the sample using the refractive member so as to provide, at a number of microstructures, a plurality of illumination angles simultaneously,

- collecting light diffracted from the illuminated microstructures using a collection system, and resolving the collected light into diffraction data relating to illumination angles, polarization angles, diffraction orders, and illumination wavelengths, and

- determining the geometrical profile of the illuminated microstructures using a reconstruction algorithm, the reconstruction algorithm comprising the steps of:

    - comparing the resolved diffraction data with modeled diffraction data from a known geometrical profile, the known geometrical profile being selected from a database of pre-defined families of profiles, the selection being performed using minimum norm techniques,

    - repeating adjusting the geometrical profile of the known selected geometrical profile until the modeled diffraction data matches the resolved diffraction data within predetermined tolerances.

15. Use of the method according to claim 14 for monitoring formation or alternation of periodic microstructures.

16. The use of the method according to claim 15, wherein the formation or alternation is monitored by monitoring respective formation or alternation of the microstructures.

17. The use of the method according to claim 15, wherein the formation or alternation is monitored by monitoring formation or alternation of an associated target structure.

18. The use of the method according to claim 15, wherein the periodic microstructures are formed or altered in a semiconductor, metallic, or dielectric material, or combination thereof.

19. The use of the method according to claim 18, wherein the periodic microstructures are formed or altered using an etching method, such as reactive plasma etching and wet etching.

20. The use of the method according to claim 18, wherein the periodic microstructures are formed using a lithographic process.

21. The use of the method according to claim 18, wherein the periodic microstructures are formed or altered using an epitaxial growth process.

22. The use of the method according to claim 18, wherein the periodic microstructures are formed or altered using a film deposition process.

23. The use of the method according to claim 18, wherein the periodic microstructures are formed or altered using an oxidation process.

24. A computer program code for determining a geometrical profile of illuminated microstructures when said program code is run on a computer, the program code being adapted to perform the following steps:

- resolving collected light data into diffraction data relating to illumination angles, polarization angles, diffraction orders, and illumination wavelengths,

- comparing the resolved diffraction data with modeled diffraction data from a known geometrical profile, the known geometrical profile being selected from a database of pre-defined families of profiles, the selection being performed using minimum norm techniques, and

- repeating adjusting the geometrical profile of the known selected geometrical profile until the modeled diffraction data matches the resolved diffraction data within predetermined tolerances.

25. A computer readable medium carrying a computer program code for determining a geometrical profile of illuminated microstructures when said program code is run on a computer, the program code being adapted to perform the following steps:

- resolving collected light data into diffraction data relating to illumination angles, polarization angles, diffraction orders, and illumination wavelengths,

- comparing the resolved diffraction data with modeled diffraction data from a known geometrical profile, the known geometrical profile being selected from a database of pre-defined families of profiles, the selection being performed using minimum norm techniques, and

- repeating adjusting the geometrical profile of the known selected geometrical profile until the modeled diffraction data matches the resolved diffraction data within predetermined tolerances.

26. An apparatus for measuring geometrical profiles of periodic microstructures of a sample, the apparatus comprising

- a light source for emission of a light beam,

- polarizing means for polarizing the emitted light beam,

- focusing means for focusing the polarized light beam on the microstructures of the sample so as to provide, at a number of microstructures, a plurality of illumination angles simultaneously,

- a collection means for collecting light diffracted from the illuminated microstructures,

- resolving means for resolving the collected light into diffraction data relating to illumination angles, polarization angles, diffraction orders, and illumination wavelengths, and

- a reconstruction algorithm for determining the geometrical profile of the illuminated microstructures, the reconstruction algorithm being adapted to perform the following steps:

  - comparing the resolved diffraction data with modeled diffraction data from a known parameterized geometrical profile, the known parameterized geometrical profile being selected by variation of the geometrical profile parameters, the selection of the parameters being performed using minimum norm techniques,

  - repeating adjusting the geometrical profile of the known selected geometrical profile until the modeled diffraction data matches the resolved diffraction data within predetermined tolerances.

27. An apparatus according to claim 26, wherein the light source comprises a broadband light source, such as Xenon, Deuterium, or halogen lamp.

28. An apparatus according to claims 26 or 27, wherein the focusing means comprises a lens system.

29. An apparatus according to claim 26, wherein the light source comprises a substantially monochromatic light source, such as a laser.

30. An apparatus according to any of claims 26-29, wherein the collection means comprises a lens system.

31. An apparatus according to any of claims 26-30, wherein the focusing means and the collection means each comprises a lens system.

32. An apparatus according to claim 31, wherein the lens systems of the focusing means and the collection means are the same lens system.

33. An apparatus according to any of claims 26-32, wherein the polarizing means comprises a beam splitter, the beam splitter generating a reference beam and an illumination beam.

34. An apparatus according to any of claims 26-33, wherein the resolving means comprises an imaging detection system.

35. An apparatus according to claim 34, wherein the imaging detection system comprises means for generating a plurality of light beams having different center wavelengths and propagating in different directions.

36. An apparatus according to claim 35, wherein the imaging detection system further comprises an array of light sensitive elements, the array of light sensitive elements being adapted to be illuminated by the generated plurality of light beams.

37. An apparatus according to claim 34, wherein the imaging detection system comprises an array of color light sensitive elements, the color sensitivity being provided by a color mask positioned in front of the light sensitive elements.

38. An apparatus according to any of claims 36 or 37, wherein the array of light sensitive elements forms part of a CCD array, an InGaAs array, a PbSe array, a PbS array, a Superconduction Tunnel Junction array, or any combination thereof.

39. A non-destructive method for measuring geometrical profiles of periodic microstructures of a sample, the method comprising the steps of:

- providing a light source for emission of a light beam,

- polarizing the emitted light beam, and transmitting the polarized light beam to a refractive member,

- focusing the transmitted and polarized light beam on the microstructures of the sample using the refractive member so as to provide, at a number of microstructures, a plurality of illumination angles simultaneously,

- collecting light diffracted from the illuminated microstructures using a collection system, and resolving the collected light into diffraction data relating to illumination angles, polarization angles, diffraction orders, and illumination wavelengths, and

- determining the geometrical profile of the illuminated microstructures using a reconstruction algorithm, the reconstruction algorithm comprising the steps of:

  - comparing the resolved diffraction data with modeled diffraction data from a known parameterized geometrical profile, the known parameterized geometrical profile being selected by variation of the geometrical profile parameters, the selection of the parameters being performed using minimum norm techniques,

  - repeating adjusting the geometrical profile of the known selected geometrical profile until the modeled diffraction data matches the resolved diffraction data within predetermined tolerances.

40. Use of the method according to claim 39 for monitoring formation or alternation of periodic microstructures.

41. The use of the method according to claim 40, wherein the formation or alternation is monitored by monitoring respective formation or alternation of the microstructures.

42. The use of the method according to claim 40, wherein the formation or alternation is monitored by monitoring formation or alternation of an associated target structure.

43. The use of the method according to claim 40, wherein the periodic microstructures are formed or altered in a semiconductor, metallic, or dielectric material, or combination thereof.

44. The use of the method according to claim 43, wherein the periodic microstructures are formed or altered using an etching method, such as reactive plasma etching and wet etching.

45. The use of the method according to claim 43, wherein the periodic microstructures are formed using a lithographic process.

46. The use of the method according to claim 43, wherein the periodic microstructures are formed or altered using an epitaxial growth process.

47. The use of the method according to claim 43, wherein the periodic microstructures are formed or altered using a film deposition process.

48. The use of the method according to claim 43, wherein the periodic microstructures are formed or altered using an oxidation process.

49. A computer program code for determining a geometrical profile of illuminated microstructures when said program code is run on a computer, the program code being adapted to perform the following steps:

- resolving collected light data into diffraction data relating to illumination angles, polarization angles, diffraction orders, and illumination wavelengths,

- comparing the resolved diffraction data with modeled diffraction data from a known parameterized geometrical profile, the known parameterized geometrical profile being selected by variation of the geometrical profile parameters, the selection of the parameters being performed using minimum norm techniques, and

- repeating adjusting the geometrical profile of the known selected geometrical profile until the modeled diffraction data matches the resolved diffraction data within predetermined tolerances.

50. A computer readable medium carrying a computer program code for determining a geometrical profile of illuminated microstructures when said program code is run on a computer, the program code being adapted to perform the following steps:

- resolving collected light data into diffraction data relating to illumination angles, polarization angles, diffraction orders, and illumination wavelengths,

- comparing the resolved diffraction data with modeled diffraction data from a known parameterized geometrical profile, the known parameterized geometrical profile being selected by variation of the geometrical profile parameters, the selection of the parameters being performed using minimum norm techniques, and

- repeating adjusting the geometrical profile of the known selected geometrical profile until the modeled diffraction data matches the resolved diffraction data within predetermined tolerances.